CLAIMS

I claim:

1. A method of radio frequency communication, the method comprising:

transmitting a first signal at a first frequency from a first transponder to a second transponder;

phase locking on the first signal to create a reference signal;

transmitting a second signal at a second frequency from the first transponder to the second transponder;

comparing the second signal to the reference signal; and

determining a distance between the first and second transponders based on a phase difference between the second and reference signals.

2. The method of claim 1 wherein the first transponder is an interrogator and the second transponder is an RF tag.

3. The method of claim 2, further comprising

receiving a radio frequency interrogation signal from the interrogator;

modulating the interrogation signal according to an information code to produce a response signal; and

transmitting the response signal from the RF tag to the interrogator.

4. The method of claim 1 wherein the comparing step includes mixing the reference signal with the second signal to obtain a mixed signal and the determining step includes determining how many nulls or peaks there are in the mixed signal.

5. The method of claim 4 wherein the step of determining how many nulls or peaks there are in the mixed signal is performed at the second transponder and the step of determining the distance between the first and second transponders includes transmitting to the first transponder an indication of the how many nulls or peaks there are in the mixed signal and determining the distance from the indication and the first and second frequencies.

6. The method of claim 1 wherein the distance determined is a first distance and the first and second signals are transmitted via a first antenna of the first transponder, the first transponder having a second antenna spaced apart from the first antenna, the method further comprising:

determining a second distance between the second antenna of the first transponder and the second transponder based on a phase difference between the signals transmitted through the second antenna; and

determining a direction from the first transponder to the second transponder based on the first and second distances and a distance between the first and second antennas.

7. The method of claim 1 wherein the reference signal is a first reference signal and the first and second signals are transmitted via a first antenna of the first transponder, the method further comprising:

transmitting a third signal at the first frequency from a second antenna of the first transponder to the second transponder;

phase locking on the third signal to create a second reference signal;

transmitting a fourth signal at the second frequency from the second antenna of the first transponder to the second transponder;

comparing the fourth signal to the second reference signal;

determining a distance between the second antenna of the first transponder and the second transponder based on a phase difference between the fourth signal and the second reference signal; and

determining a location of the second transponder based on the distances determined.

8. The method of claim 1 wherein the second signal is a frequency modulated signal that includes a plurality of frequency portions at a plurality of frequencies.

9. The method of claim 1 wherein:

the step of transmitting the second signal includes transmitting a plurality of frequency portions each at a different frequency;

the comparing step includes comparing each of the frequency portions to the reference signal by mixing each of the frequency portions with the reference signal to produce a plurality of mixed signals; and

the distance determining step includes counting nulls or peaks in each of the mixed signals.

10. A method of radio frequency communication, the method comprising:

transmitting a first signal at a first frequency from a first transponder to a second transponder;

transmitting a second signal at a second frequency from the first transponder to the second transponder;

comparing the second signal to the first signal; and

determining a distance between the first and second transponders based on a phase difference between the first and second signals.

11. The method of claim 10 wherein the first transponder is an interrogator and the second transponder is an RF tag.

12. The method of claim 11, further comprising:

receiving a radio frequency interrogation signal from the interrogator;

modulating the interrogation signal according to an information code to produce a response signal; and

transmitting the response signal from the RF tag to the interrogator.

13. The method of claim 11 wherein the comparing step is performed by the RF tag and includes phase locking on the first signal to create a reference signal and mixing the reference signal with the second signal to obtain a mixed signal; and the determining step includes determining how many nulls or peaks there are in the mixed signal.

14. The method of claim 13 wherein the step of determining how many nulls or peaks there are in the mixed signal is performed at the second transponder and the step of determining the distance between the first and second transponders includes transmitting to the first transponder an indication of the how many nulls or peaks there are in the mixed signal and determining the distance from the indication and the first and second frequencies.

15. The method of claim 10 wherein the distance determined is a first distance and the first and second signals are transmitted via a first antenna of the first transponder, the first transponder having a second antenna spaced apart from the first antenna, the method further comprising:

determining a second distance between the second antenna of the first transponder and the second transponder based on a phase difference between the signals transmitted through the second antenna; and

determining a direction from the first transponder to the second transponder based on the first and second distances and a distance between the first and second antennas.

16. The method of claim 10 wherein the first and second signals are reflected back to the first transponder by the second transponder and the comparing and determining steps are performed by the first transponder.

17. The method of claim 10 wherein the distance determined is a first distance, the method further comprising:

moving the first transponder from a first position, from which the first distance is determined, to a second position;

transmitting a third signal at the first frequency from the first transponder to the second transponder;

transmitting a fourth signal at the second frequency from the first transponder to the second transponder;

comparing the fourth signal to the third signal;

determining a second distance between the first and second transponders based on a phase difference between the third and fourth signals; and

determining a location of the second transponder based on the first and second distances and the first and second positions of the first transponder.

18. The method of claim 10 wherein the second signal is a frequency modulated signal that includes a plurality of frequency portions at a plurality of frequencies.

19. The method of claim 10 wherein:

the step of transmitting the second signal includes transmitting a plurality of frequency portions each at a different frequency;

the comparing step includes comparing each of the frequency portions to the reference signal by mixing each of the frequency portions with the reference signal to produce a plurality of mixed signals; and

the distance determining step includes counting nulls or peaks in each of the mixed signals.

20. A radio frequency communication system, comprising:

an interrogator that transmits a radio frequency interrogation signal and receives a response signal; and

a transponder that receives the interrogation signal and transmits the response signal to the interrogator, the transponder including:

a memory that stores an information code; and

a modulator coupled to the memory and structured to produce the response signal by modulating the interrogation signal according to the information code wherein a first one of the transponder and interrogator includes a variable frequency source that transmits to a second one of the transponder and interrogator a first signal at a first frequency followed by a second signal at a second frequency; of the transponder and interrogator includes a phase comparison circuit that detects phase shifts in the second signal relative to the first signal; and one of the transponder and interrogator includes a distance determiner that determines the transponder and the interrogator based on the phase shifts.

21. The communication system of claim 20 wherein the interrogator includes the variable frequency source and the transponder includes the phase comparison circuit.

22. The communication system of claim 21 wherein the phase comparison circuit includes:

a phase lock loop that phase locks on the first signal to produce a reference signal;

a mixer coupled to the phase lock loop and structured to mix the reference signal with the second signal to obtain a mixed signal; and

a counter coupled to the mixer and structured to determine a null or peak count of how many nulls or peaks there are in the mixed signal.

23. The communication system of claim 22 wherein the interrogator includes means for calculating the distance between the interrogator and the transponder based on the null or peak count which is sent to the interrogator by the transponder.

24. The communication system of claim 20 wherein the interrogator includes the variable frequency source and the phase comparison circuit.

25. The communication system of claim 20 wherein the second signal is a frequency modulated signal.

26. A radio frequency transponder, comprising:

an antenna that receives from an interrogator first and second signals having first and second frequencies, respectively;

a phase lock loop coupled to the antenna and structured to phase lock on the first signal to create a reference signal;

a comparator coupled to the antenna and phase lock loop and structured to compare the second signal to the reference signal; and

means for determining a phase difference between the second and reference signals, the phase difference corresponding to a distance between the first and second transponders.

27. The transponder of claim 26 wherein the comparator includes a mixer structured to mix the reference signal with the second signal to obtain a mixed signal; and the means for determining include a counter coupled to the mixer and structured to determine a null count of how many nulls there are in the mixed signal.

28. A radio frequency interrogator, comprising:

a variable frequency signal source that produces a first signal at a first frequency and a second signal at a second frequency;

antenna means coupled to the signal source for transmitting to a transponder the first and second signals and for receiving the first and second signals reflected back from the transponder;

a comparator coupled to the antenna and structured to compare the reflected second signal to the reflected first signal; and

means for determining a distance between the first and second transponders based on a phase difference between the reflected first signal and the second signal.

29. The radio frequency interrogator of claim 28 wherein the comparator includes a mixer that mixes the second signal with the reflected first signal to produce a mixed signal and the means for determining includes a null or peak counter that counts nulls or peaks in the mixed signal; and

a processor structured to determine the distance based on the nulls or peaks in the mixed signal.